Dam Technologies of Japan

Japanese Advanced Technologies can Meet
All of Your Needs about Dams
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1. High Durability and Earthquake-resistance of Dams can Reduce LCC

Japanese dams have endured major earthquakes owing to Japanese dam technologies.

High durability of dams together with speedy construction can reduce life cycle cost (LCC).

Reduce LCC through Total Quality Management.
Japanese Advanced Technologies can Meet All of Your Needs about Dams

2. Upgrading Technologies to Effectively Use Existing Dams

- Restoring dam function (Control sediment)
- Increasing reservoir volume under operation
- Construction to enable more effective use of reservoir water under operation
- Upgrading power plant
- Increasing the volume of the water supply
Japanese Advanced Technologies can Meet All of Your Needs about Dams

3. Environmentally Friendly Technologies to Conserve the Environment and Ecosystem

Conserving water quality in the reservoir

Conserving the ecosystem

Monitoring for the water quality and environment during construction
Japanese Advanced Technologies can Meet All of Your Needs about Dams

Dams are very useful in hydroelectric power generation, water resource development, flood control, and other areas. Furthermore, dams must continue to function and must not break down.

Japanese advanced technologies can construct sound dams, even using less-than-ideal materials on less-than-ideal foundations, within a short period of time and with low cost. They will have excellent qualities such as high strength, high durability, and resistance to earthquakes, which will also yield very low life-cycle cost (LCC).

Japanese advanced technologies can also rehabilitate and upgrade existing dams under operation. These technologies can increase reservoir volume and discharge capacity, improve operations, control sediment, and other benefits.

Japanese advanced technologies can also conserve the natural and social environments during construction or under operation. Conserving water quality, ecosystems, and living environments are examples of this conservation.

If you select us as your partner, you will gain a good opportunity to obtain our advanced technologies and grow your local economies through good partnership with us.
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1. High Durability and Earthquake-resistance of Dams can Reduce LCC

Japanese dams have endured major earthquakes owing to Japanese dam technologies

The history of modern dam construction in Japan began in 1887 when an earth dam to collect water for water supply was built. Japan’s first concrete dam to supply water was completed in 1900. The older of the two (the earth dam) was damaged by massive flooding in 1982. The concrete dam was damaged by the Great Hanshin (Kobe) Earthquake in 1995, which measured 7.3 on the Richter scale. Both dams are still in service, even though they suffered minor damages under frequent occurrence of major natural disasters.

Dams designed and built with the Japanese current technical standards have endured the Great Hanshin Earthquake and the later, more powerful Great East Japan (Tohoku) Earthquake (magnitude 9.0) in 2011, and are all in service.

Fig. 1-1 Japan’s oldest modern earth dam, completed in 1887

Fig. 1-2 Japan’s oldest concrete dam, completed in 1900

Japan is the most vulnerable country to earthquakes in the world; therefore, not only dam bodies but all related facilities are reviewed for safety against “Level 2 seismic motion” that is the strongest possible earthquake motion at the dam site (Fig. 1-3).

Fig. 1-3 Procedures in testing to verify earthquake resistance
High durability of dams together with speedy construction can reduce life cycle cost (LCC). Roller Compacted Dam (RCD) and Trapezoidal CSG Dam are Japan’s two major dam construction methods that are unique to this country. These methods ensure dam high durability through advanced quality control measures, while enabling speedy construction. Dams built using these methods cost less to maintain; therefore, their LCC (assuming a service life of at least 100 years) are significantly lower than those of less durable dams.

Here’s an outline of these two construction methods.
Features of RCD Dams

Design Characteristics of RCD Dams

RCD is a construction method to rationalize the dam construction works and the required functions of RCD dams should be completely the same as those of conventional concrete gravity dams.

- Climate changes with the season in Japan
- Concrete gravity dams need a certain amount of dead weight
- Earthquake-prone Japan

**Durability**  
**Density**  
**Strength and water-tightness**  
**Reliable bond of construction joints**

Concretes with several kinds of mix proportion design share roles in constructing a safe dam as a conventional dam.

- Take precautions so that construction joints do not form weak planes.

RCD concrete is used as internal concrete.

- Thicken each lift to reduce the frequency of joint treatment.

Treat appropriately construction joints to prevent decrease in strength.  
① Green cutting and cleaning.  
② Placing of mortar before placement of concrete in contact with the hardened concrete.

<table>
<thead>
<tr>
<th>Types of concrete</th>
<th>Roles</th>
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<tbody>
<tr>
<td>① External concrete</td>
<td>Provide appropriate water-tightness and durability.</td>
</tr>
<tr>
<td>② Structural concrete</td>
<td>Provide appropriate strength to resist the generated internal stress.</td>
</tr>
<tr>
<td>③ Foundation concrete</td>
<td>Provide appropriate concrete placement performance despite irregularities in the rock foundation surface.</td>
</tr>
<tr>
<td>④ Internal concrete</td>
<td>Provide appropriate strength and density.</td>
</tr>
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</table>

Constitution Characteristics of RCD Dams

Thickening of lift and thin-layer spreading

Thin spreading of RCD concrete  
Compaction with vibratory roller

Construction joint treatment and spreading mortar

Green-cutting with a polisher robot  
Green-cutting machine  
Spreading mortar
Cruising RCD construction method

The cruising RCD construction method was developed to realize a more efficient and faster RCD construction method without losing its important feature to ensure the functions of conventional concrete dams.

1. Advance placement of RCD concrete
   RCD concrete generally must be placed quickly in large quantities, so this method begins with the advance placement of RCD concrete. It is not placed alternately with external concrete, so high speed placement of RCD concrete can be maintained.

2. Independent and subsequent placement of external concrete
   The method allows independent placement of external concrete, ensuring freer and safer placing.

   - Feature 1: High speed placement from the beginning
   - Feature 2: Can maintain high speed

3. Stopping and restarting placement of RCD concrete without forms
   The method allows placement of RCD concrete to be stopped independently of other concrete.

   - Feature 3: Permits placement until just before the rain halts
   - Feature 4: Speeds restarting of placement

Cruising RCD construction method cycle (continuous placement without sectioning)
Concept of Trapezoidal CSG Dam

Characteristics of the Trapezoidal CSG

(Rationalization of design)
Trapezoidal Dam is able to:
① Control the stress generated within the dam body even in the event of a large-scale earthquake;
② Control stress fluctuation within the dam body even if loading conditions change;
③ Enhance safety against sliding or overturning.

(Rationalization of Materials/Construction)
CSG Construction Method is able to:
① Reduce environmental burden and costs by effectively utilizing materials that can be easily obtained near the construction sites;
② Reduce construction costs by omitting an aggregate facility and simplifying construction facilities;
③ Achieve rapid execution works by using general-purpose machines.

Trapezoidal CSG Dam

[Rationalization of Materials]
Since the strength required of the dam materials is low, the performance level required of the materials is low. Therefore, material selection can be highly flexible.

[Rationalization of Design]
The strength required of dam materials can be lessened with the seismic stability improved by shaping the dam as a trapezoid.

[Rationalization of Construction]
Construction work can be executed rapidly by simplified construction facilities.

Standard Cross Section of the Trapezoidal CSG Dam

- Protection Concrete
- CSG
- Structural Concrete
- Inspection Gallery
- Seepage Control Concrete
- Rich-mix CSG
- Foundation Drain Hole
- Auxiliary Curtain Grouting
- Curtain Grouting
Trapezoidal CSG Dam Construction Flow

Tobetsu Dam (View from the right bank)

CSG Method (Construction Flow in Tobetsu Dam)

Raw Material
Riverbed gravel, Excavated rock etc.

Mixing
Adding Cement and Water

Extraction
Riverbed gravel

Fresh CSG

Transport
Off-Highway Trucks (55ton)

Compacting
Vibrating Roller (11ton)

Bulldozing
Track-Type Tractors (28ton)
Reduce LCC through Total Quality Management (TQM)

"Smart" construction utilizing information and communication technologies (ICT) can make the work process more efficient and accurate. By using ICT, data can be shared and made traceable so it can be used to ensure quality. This is an example of the Total Quality Management (TQM) effort in dam construction to ensure uniform dam quality, make dams more durable and thereby reduce their life cycle cost.

Source: Ministry of Land, Infrastructure, Transport and Tourism

Fig. 1-4 Cycle, Construction
For a dam to function over a long period of time it should be constantly repaired and maintained. The cost required for dam maintenance, repair and renewal is low at the beginning, but equipment needs to be renewed after about 10 years. After 40-50 years, major rebuilding will be needed. Maintenance programs aiming at “longer service life” and “reduced maintenance costs” should be made so that dams can be maintained efficiently within limited budgets.

**[Systems to ensure a longer service life and their advantages]**

Fig. 1-6 shows an example of a system to maintain the dam at low cost and ensure a longer service life. Overall costs can be reduced and allocated evenly through planned maintenance and repairs to the dam.

<table>
<thead>
<tr>
<th><strong>STEP 1 (Formulating the basic policy)</strong></th>
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<tbody>
<tr>
<td>① Understanding the current state of the dam and uncovering</td>
</tr>
<tr>
<td>- Organize inspection program and data available</td>
</tr>
<tr>
<td>- Estimate maintenance costs</td>
</tr>
<tr>
<td>- Identify state of maintenance and any issues</td>
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<tr>
<td>② Formulation of a maintenance plan</td>
</tr>
<tr>
<td>- Identify management data items</td>
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<tr>
<td>- Establish inspection methods</td>
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<tr>
<td>- Create methods to evaluate the soundness of the dam</td>
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<tr>
<td>- Sorting out the causes of deterioration</td>
</tr>
<tr>
<td>- Establish the water level observation method to be managed</td>
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<tr>
<td>- Determine priorities</td>
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<tr>
<th><strong>STEP 2 (Periodic inspections)</strong></th>
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<tbody>
<tr>
<td>③ Periodic dam inspections</td>
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<tr>
<td>- Inspect in accordance with standards</td>
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<tr>
<td>- Collect and organize management records</td>
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<tr>
<td>- Conduct on-site surveys and inspections</td>
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<tr>
<td>- Evaluate and prepare periodic inspection reports</td>
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<tr>
<td>- Use data to improve the dam</td>
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<tr>
<th><strong>STEP 3</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>④ Revision of the maintenance plan</td>
</tr>
<tr>
<td>- Verify the quantitative effectiveness of the maintenance plan</td>
</tr>
<tr>
<td>- Renewal plan on priority basis (preventative maintenance, post-event maintenance)</td>
</tr>
<tr>
<td>- Study ways to even-out maintenance in the face of budget cuts</td>
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</tbody>
</table>

**Merits to be gained**

- Large variation in maintenance costs from one year to the next
- Carrying out periodic repairs and renewals is linked to lower and more evenly spread maintenance costs

Fig. 1-6 A System to enable a dam to be used over a long period at low cost
2. Upgrading Technologies to Effectively Use Existing Dams
(Reduce Costs, Construction Periods, Environmental Impacts)

Using Japan’s dam upgrading technologies, the functions of existing dams (reservoir volume, discharge capacity, operation and control sediment) can be improved under operation, so that the dams' functions can be maintained at their maximum level.

- Increasing reservoir volume under operation
  【Raising the dam body】

The height of the dam can be raised under operation, to increase reservoir volume. To do this, the safety of the existing dam is assessed, ways to unify the old dam with the new construction are examined, and the stability of the foundation and the newly constructed dam extension is examined. Even old dams can be made higher following detailed and careful assessment.

- Raising concrete dams(Fig.2-1)

- Raising fill dams(Fig.2-2)
Construction to enable more effective use of reservoir water under operation

(Improving operation, Increasing discharge capacity)

[Upgrading power plant]

With Japan’s upgrading technologies we can expand or install power plant while the dam is in service.

Fig. 2-3 Expanding the power plant
(Source: New Energy Foundation)

[Increasing the volume of the water supply and discharge capacity]

Using Japan’s upgrading technologies, we can drill the dam body and build a water intake in the existing dam under operation, and thus increase the water supply and discharge capacity. The selective intake facility can be built at any depth in the dam to take water at the temperature required for use. The water is warmer and clearer near the surface, while water near the bottom is colder and muddier.

Fig. 2-4 Expanded power plant
(Source: Ministry of Economy, Trade and Industry)

Fig. 2-5 Addition of a selectable water intake facility to a dam in service

(Source: Mie Matsuzaka building Office Miyakawa Dam Management Office)
【Technologies used for construction】

- Construction Technologies in deep reservoir

To carry out construction work under operation, the water level upstream from the dam should not be lowered. To maintain the water level a large-scale barrier should be built upstream. Japan has deep-water construction technology that can effectively place the barrier in the water to maintain the water level during construction.

For more information refer to http://www.qsr.mlit.go.jp/sendai/ or contact the Sendaigawa River Office.

Fig.2-6 Deep-water saturation diver at work

- Drilling the existing dam body technology

When drilling the dam body to make a tunnel and install conduits used to supply or discharge water, techniques to minimize the effect and stress on the dam body are required. Japan has both sophisticated drilling technologies that place less stress on the dam body as well as advanced technologies to assess the impact of the drilling on safety.

Fig.2-7 Drilling dam body

Fig.2-8 Analyzing the dam body while tunneling

Fig.2-9 High-precision dam body tunneling technology
**Restoring dam function (Control sediment)**

Japan has technologies to restore dam performance and make dams last longer under operation.

【Sediment bypass tunnel】

Sediment bypass tunnel is a technique used to prevent sediment flowing into the dam reservoir by bypassing it into a tunnel leading downstream from the dam. Using this technique, reservoir volume reduction resulting from sediment accumulation is minimized, allowing the dam to be used longer.

【Sediment suction techniques】

・Mobile siphon suction for sediment removal

A non-powered siphon is used to suck and remove the sediment that has accumulated at the bottom of the reservoir. The siphon’s intake works by itself and sucks sediment at a rate depending on the sediment density in the discharge pipe.

Fig.2-10 Sediment bypass tunnel in operation
(Source: Mibugawa Comprehensive Development Office of Construction)

Fig.2-11 Overview of a sediment bypass tunnel

Fig.2-12 Mobile siphon suction used to remove dam sediment
3. Environmentally Friendly Technologies to Conserve the Environment and Ecosystem

■ Conserving water quality in the reservoir

Japan is working hard to keep reservoir water clean and to protect the environment. Issues caused by river water remaining in the dam reservoir include variation of the water temperature and the amount of organic substances in the water, eutrophication and persistent muddy water. Some of the techniques in use are as follows:

【Water aeration systems】 (Fig.3-1)
A water aeration system installed in the reservoir circulates water, controls the growth of plankton, increases the amount of dissolved oxygen and thereby maintains and improves the water quality.

【Dam aerator fountain】 (Fig.3-2)
An aerator fountain controls the surface water temperature to stop it getting too high and preventing excessive growth of phytoplankton.

【Floating islands and artificial reefs】 (Fig.3-3)
A floating island is a floating body with planted shrubs and grass. The artificial reef prevents excessive growth of algae and keeps the dam water clean.

【Flow control barrier】 (Fig.3-4)
A barrier installed at the reservoir tail end leads muddy water and nutrient-rich water down into the depths of the reservoir to prevent excessive algal growth.
**Conserving the ecosystems**

While newly constructed dams create a new environment, they also affect the habitats and nesting grounds of birds of prey. Dams submerge the habitats of rare plants, and prevent fish going upstream and downstream. Japan has techniques to minimize the effects of dam construction on ecosystems.

**[Environmental impact assessment]**

In the planning phase of a dam construction projects, we conduct surveys on items listed in Table 1 and conduct qualitative forecasting and assessment. If a significant impact on the environment is likely, we examine methods to protect the environment and assess the impact of the activities that will be taken.

**Table 1**  
Items to be assessed to determine the impact of dam construction on the environment

<table>
<thead>
<tr>
<th>Environmental factors</th>
<th>Atmospheric environment</th>
<th>Water environment</th>
<th>Animals</th>
<th>Plants</th>
<th>Ecosystems</th>
<th>Scenic views</th>
<th>Waste, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air quality (dust)</td>
<td>Water turbidity due to sediment, water temperature, eutrophication, dissolved oxygen levels, hydrogen ion concentration (pH)</td>
<td>Important species and habitats need to be monitored</td>
<td>Important communities and species</td>
<td>Ecosystems that characterize the local region</td>
<td>Important scenic viewing points and landscape resources</td>
<td>By-products associated with construction</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 3-5**  
Example of assessment method (Water-quality simulation)
【Fish ways】
Dams restrict the flow of water in a river which then affects the fish moving upstream to lay their eggs. When a fish habitat is likely to be affected, fish ways suited to the local fish species are built. Fish ways installed in Japan include the sector-type, the lock-type and the nature-friendly-type. Advanced type of fish ways focused on specific fish species, nature-friendly fish ways that are designed to be adjusted to the reservoir water level and to ensure biodiversity among various animals and plants. A biotope is built in the course of the fish way to create an environment where animals and plants can prosper and create new habitats.

Fig.3-6  Nature-friendly fish way (Aono Dam, Hyogo Pref.)
Monitoring for the water quality and environment during construction

【Muddy water treatment】

In Japan, when discharging the muddy water that has been generated during the course of aggregate production, concrete placement and other construction work, the water should first meet a water-quality standard in order to protect the river environment. Muddy water is treated at facilities at dam construction sites (quarry sites, aggregate sites, dam sites) using poly-aluminum chloride (PAC), polymer coagulant, carbon dioxide and other chemicals.

Fig.3-7 Muddy water treatment

【Environmental monitoring(Noise, vibration and dust)】

Dam construction, using large machinery and carrying a massive amount of sand, soil and rocks, can be a source of noise, vibration and dust. To protect the local community and natural environment, levels are measured and necessary measures are taken.

Fig.3-8 Environmental monitoring(Noise, vibration and dust)